Higher order mode suppression in Triaxial cells

Different designs of Triaxial Cells

Overview

Higher order Mode Suppression in Triaxial Cells (Improvement of Triaxial Cell procedure)

- Triaxial test procedure
  - Transfer impedance, & Screening attenuation
  - Triaxial Cell
- Higher order modes
- Influence of absorbers
- Measurements
  - with and without absorber
- Conclusion
- Discussion

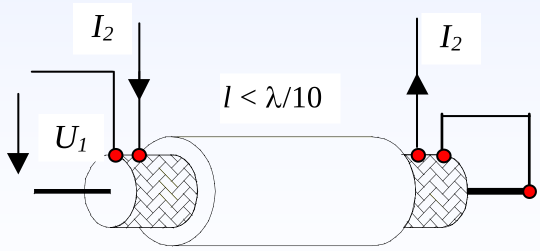
Transfer impedance & Screening attenuation

high frequencies: Screening attenuation

$$a_S = 10 \log (P_2/P_1) = 20\log_{10} (U_2/U_1) \quad [dB]$$

Ratio of two powers --> **length independent**

low frequencies: Transferimpedance



$$Z_T = \frac{U_1}{I_2 \cdot l} \quad [m\Omega/m]$$

Ratio of **U/I = R → length dependent, (Ohms law)**

Wave length
$\lambda = (c_0 \bullet v_k) / f$

electrical long:

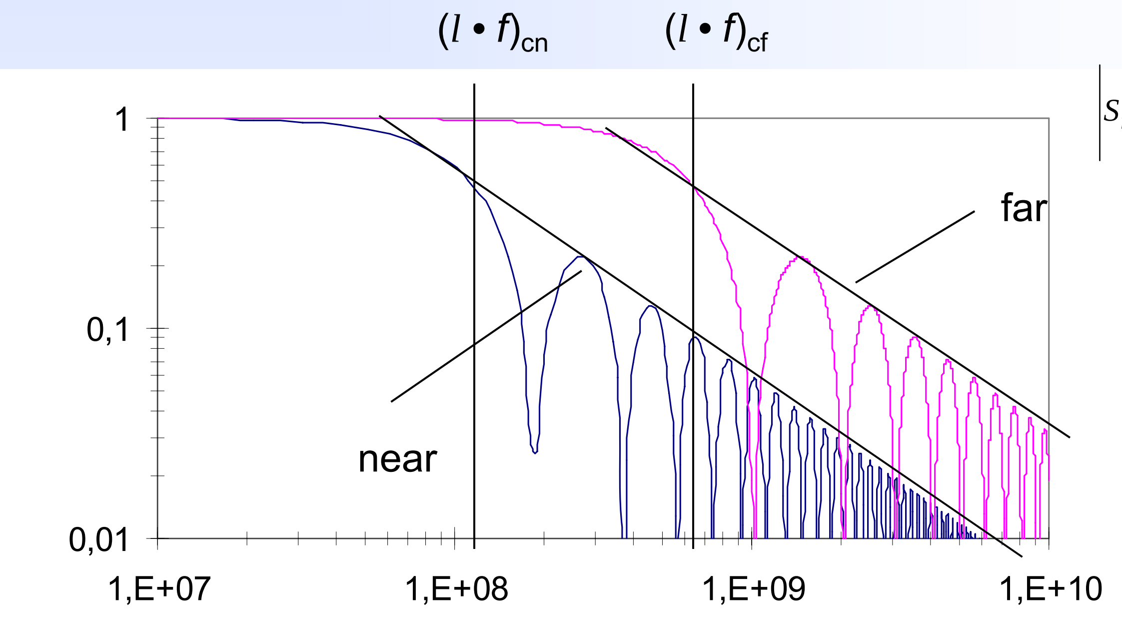
$$f > \frac{c_0}{2 \cdot l \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right|}$$

electrical short:

$$f < \frac{c_0}{10 \cdot l \cdot \sqrt{\varepsilon_{r1}}}$$

(IEC 62153-4-1)

Theory: The Summing Function S_{nf}



$$\left| S_{n\,f} \right| = \frac{\left| 2 \sin\left(\frac{(\beta_1 \pm \beta_2).L_c}{2} \right) \right|}{(\beta_1 \pm \beta_2).L_c}$$

≈ sin x/x

β represents the phase constant of the inner resp. the outer circuit

low frequencies

$$\left| S_{n\,f} \right| \rightarrow 1$$

high frequencies

$$\left| S_{n\,f} \right| \rightarrow \frac{2}{(\beta_1 \pm \beta_2) \cdot l}$$

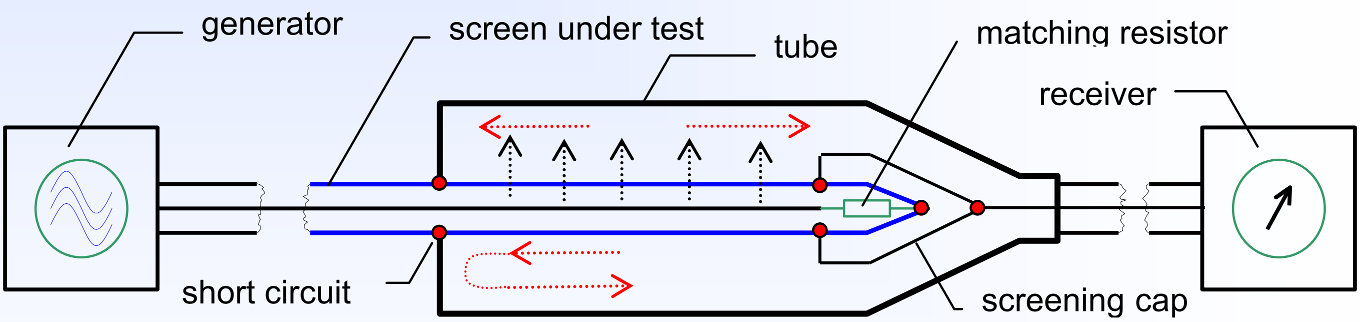
(oscillating behaviour)

introduced by Halme/Szentkuti 1988

Principle of the Triaxial test set-up

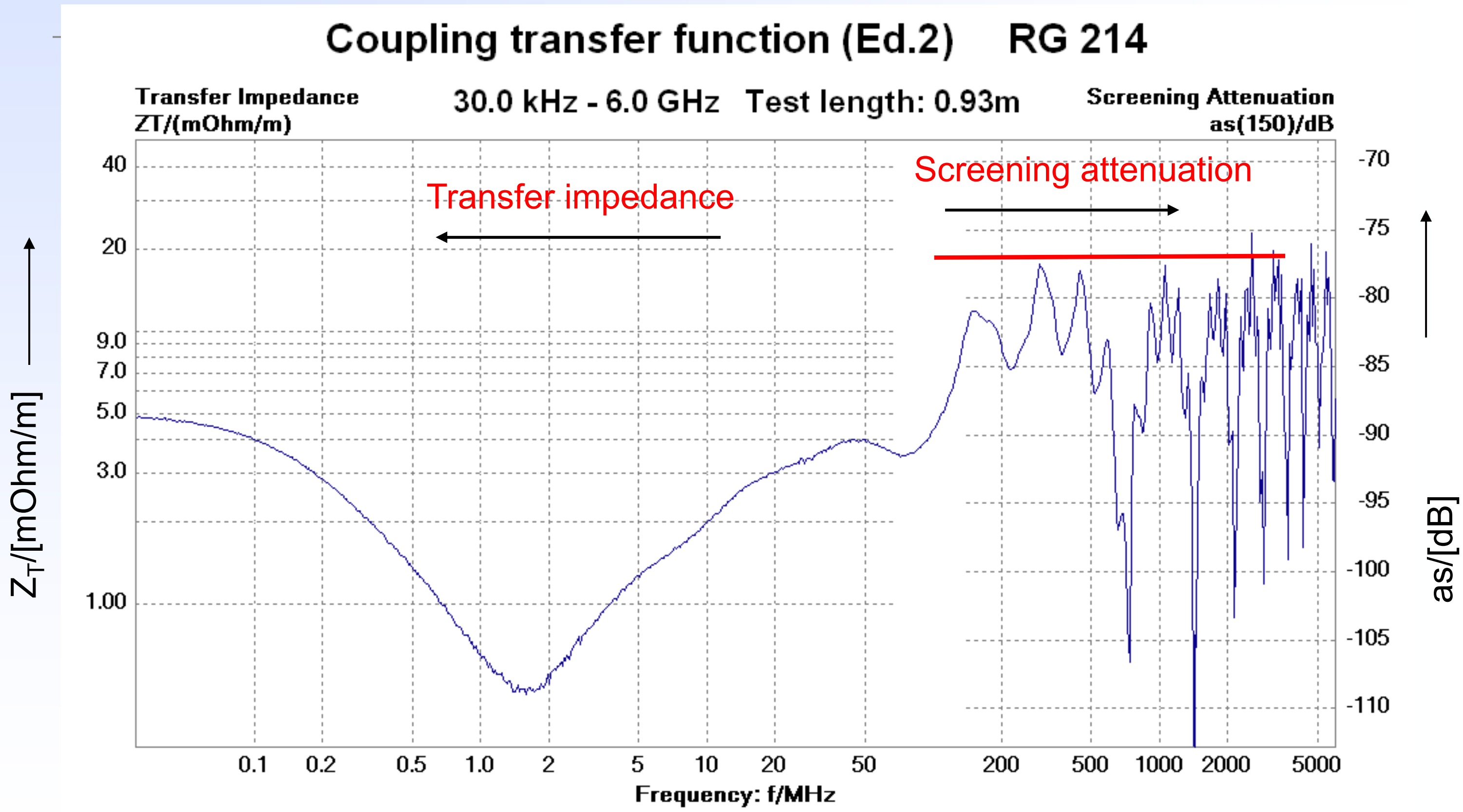
Transfer impedance & Screening attenuation

DC up to and above 12 GHz with one test set-up



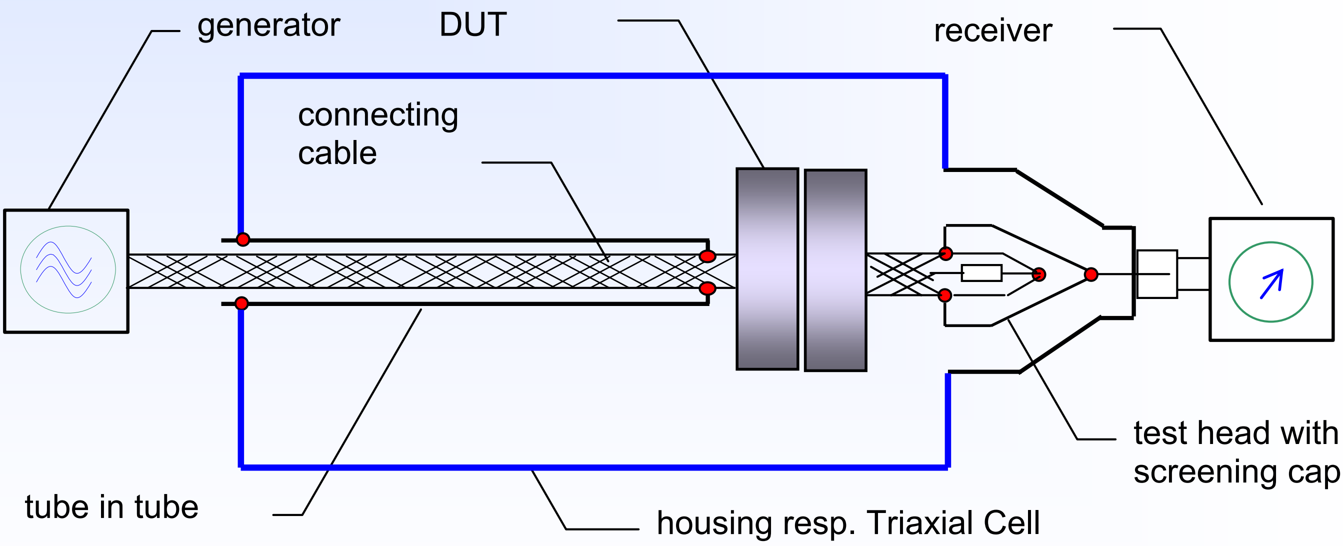
Generator and receiver are included in a modern network analyser

IEC 62153-4-3Ed2, Transfer impedance,
IEC 62153-4-4Ed2, Screening attenuation



Triaxial Cell with tube in tube, principle

The Triaxial Cell procedure is based on the principles of the Triaxial procedures according to IEC 62153-4-3, Transfer impedance and IEC 62153-4-4, Screening attenuation

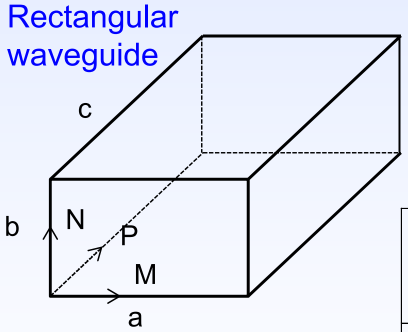


IEC 62153-4-15, Transfer impedance and Screening attenuation with Triaxial Cell

Higher order modes

The Triaxial test procedure uses the principle of Transverse electromagnetic wave propagation (TEM - waves). At higher frequencies the Triaxial cell becomes in principle a cavity resonator respectively a Rectangular waveguide which exhibits resonances depending on its dimensions. Above these resonance frequencies, propagation of TEM - waves is disturbed and measurements of screening attenuation with triaxial test method are limited.

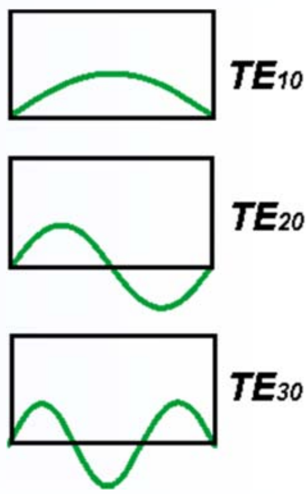
Rectangular waveguide



Resonance frequencies f_r are given by:

$$f_{mnp} = \frac{c_0}{2}\sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2 + \left(\frac{P}{c}\right)^2}$$

M,N,P	are the numbers of modes, where M,N stands for the transverse and P for the longitudinal integral multiple of the half of a wavelength (M,N,P = 1,2,3 where M or N can be set to zero)
a,b,c	are the dimensions of cavity; where a,b are coupled to the transverse and c to the longitudinal dimension
c_0	is the velocity of light in free space

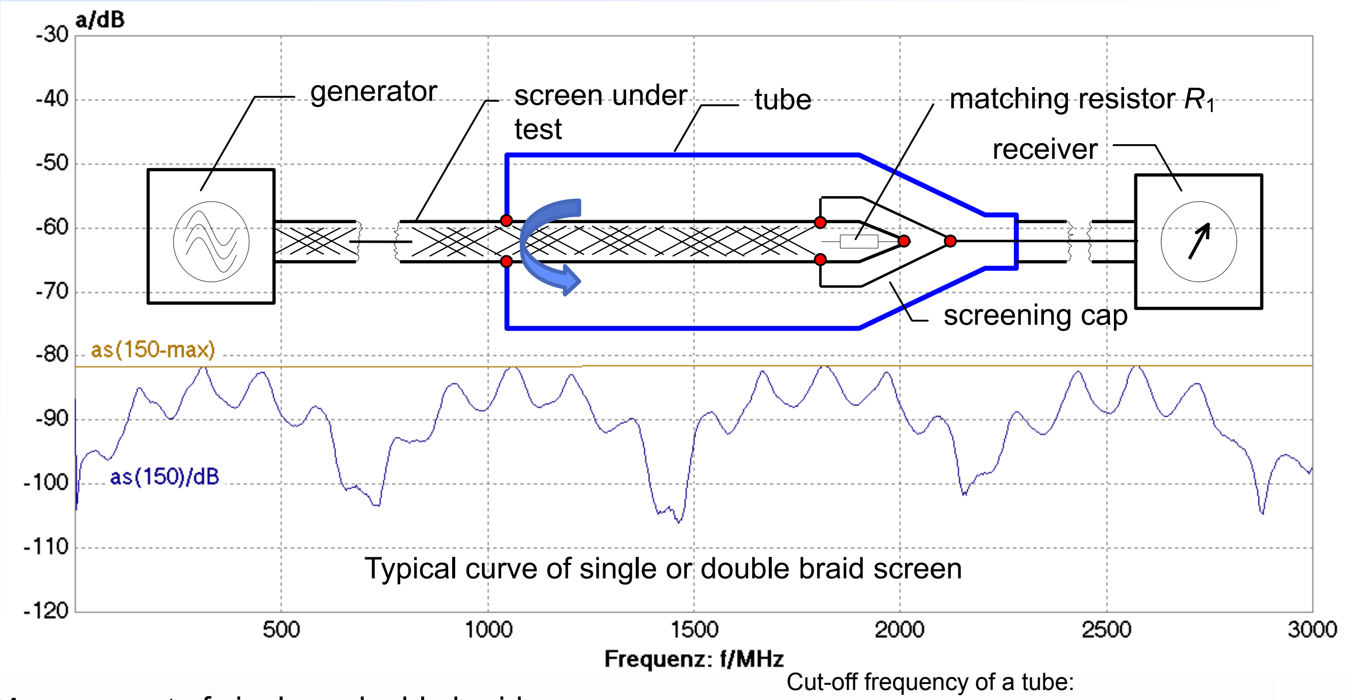


The cut-off frequency f_c of a cavity is given by:

$$f_c = \frac{c_0}{2a}$$

f_c = 500 MHz for Cell 1000/300/300 and 1 GHz for Cell 1000/150/150

Double braid RG 214 with tube 40 mm



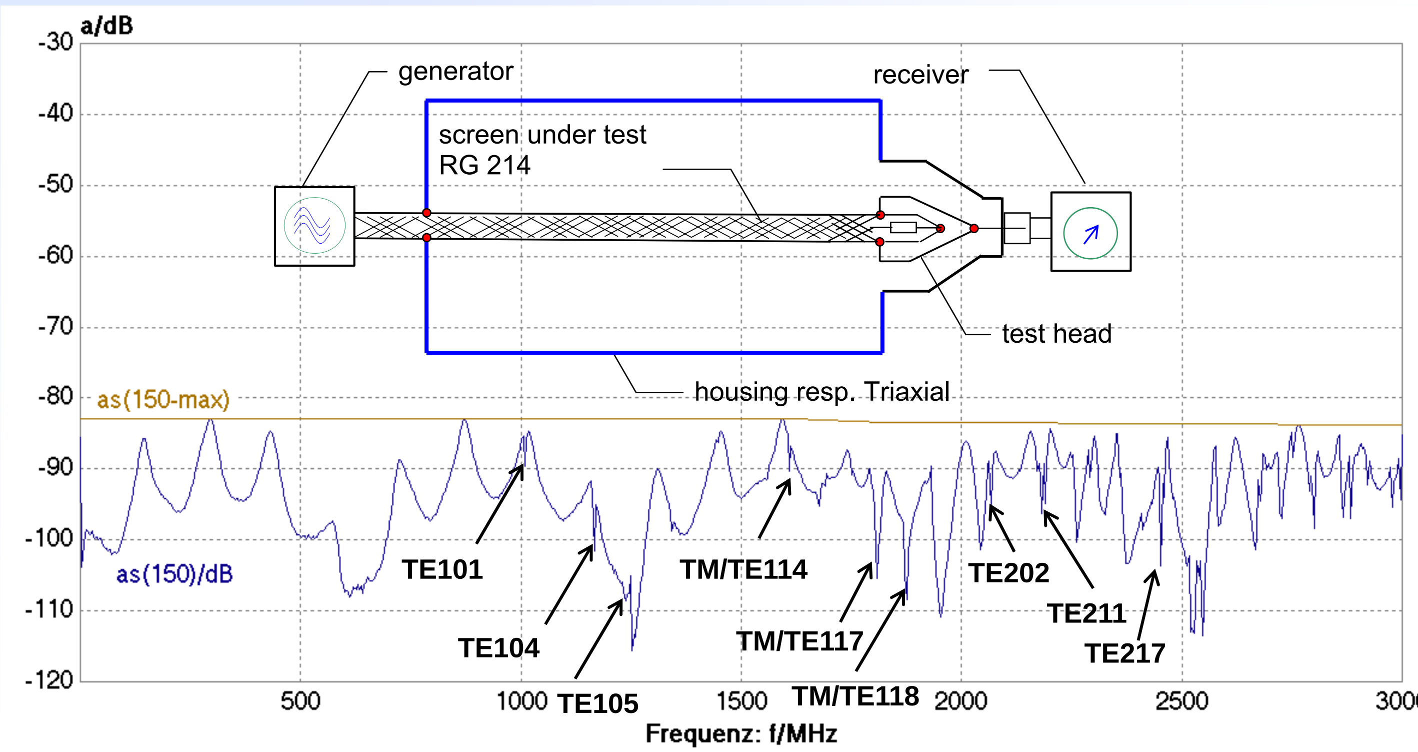
Measurement of single or double braid screen in the tube is regarded as reference measurement

Cut-off frequency of a tube:

$$f_c = \frac{2 \cdot c_0}{\pi \cdot \sqrt{\varepsilon_{r2}} \cdot (D_2 + d_1)}$$

CoMeT 40 ≈ 4,3 GHz

Higher order modes, Cell 1000/150/150



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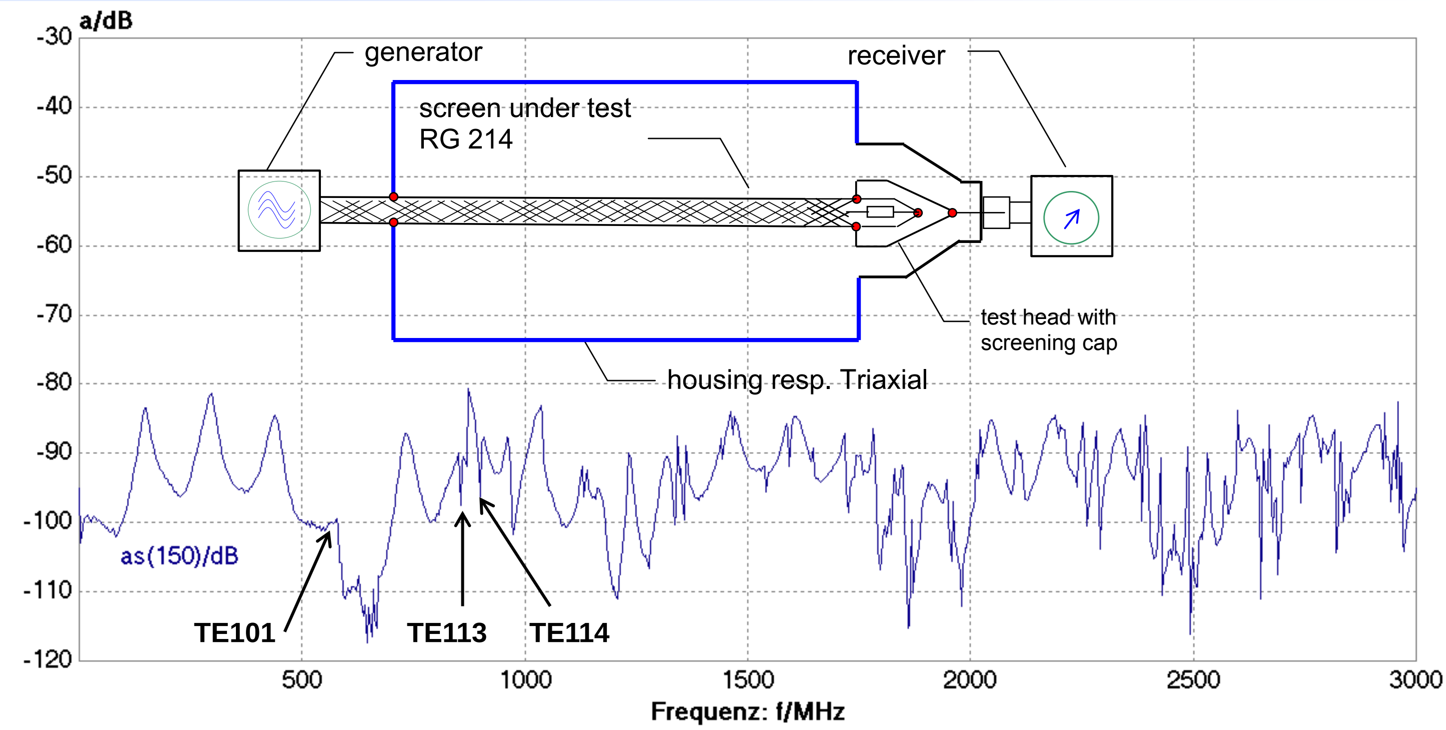
Higher order modes, Cell 1000/300/300



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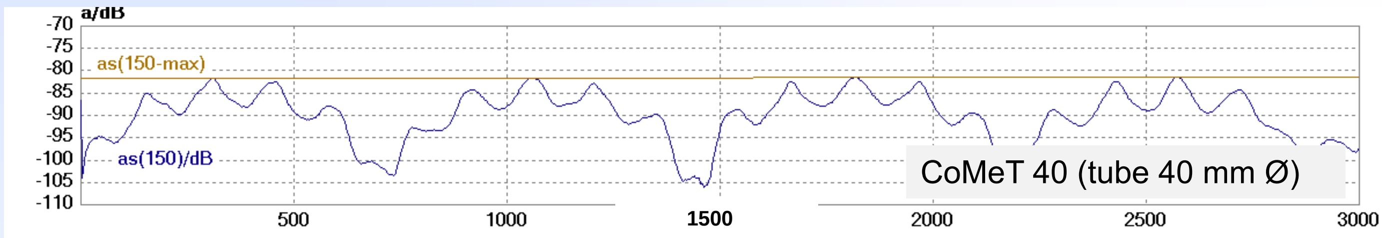
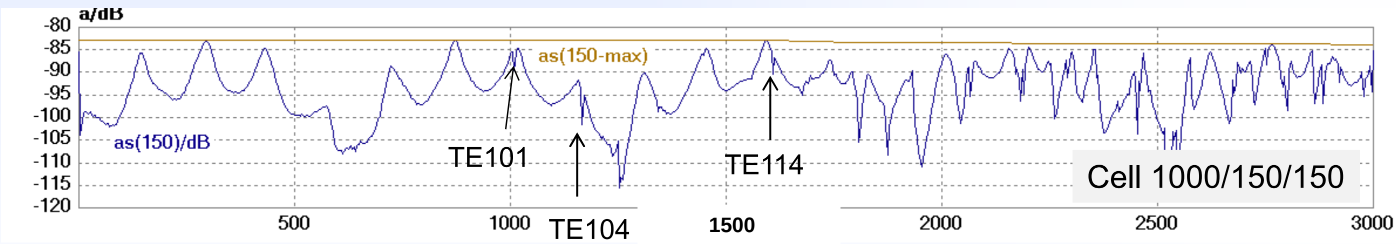
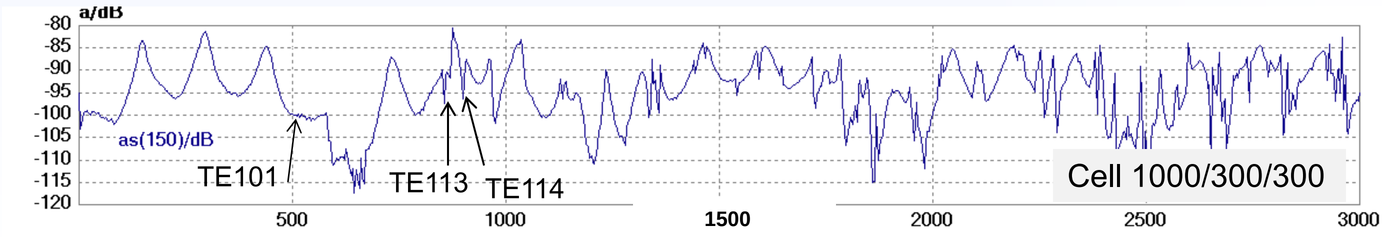
Higher order modes in different Triaxial set-ups

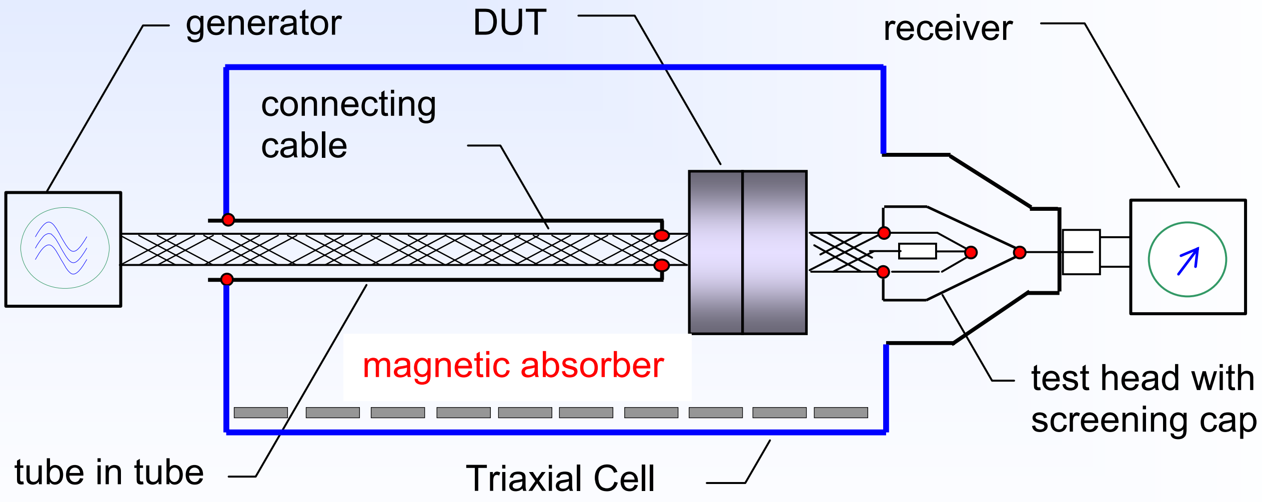






Triaxial Cell with magnetic absorber

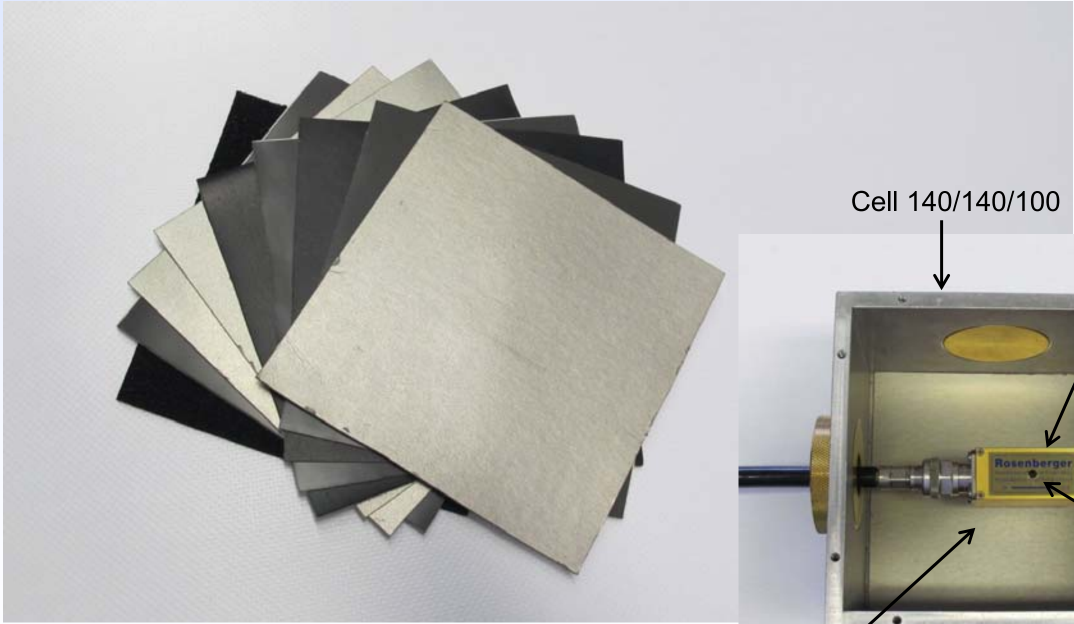
Higher order modes can be easily suppressed by using absorbing materials like ferrite tiles or by nanocrystalline or by magnetic absorbers placed in the Cell

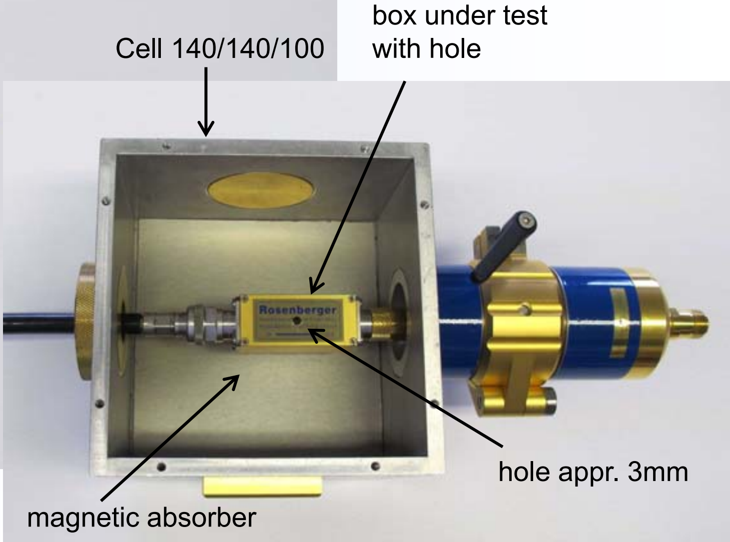


IEC 62153-4-15, Transfer impedance and Screening attenuation with Triaxial Cell

Magnetic absorbers

Although other absorber material like ferrites or nanocrystalline absorbers could be useful, measurements were performed with magnetic absorbers due to the good mechanical characteristics and easy handling.





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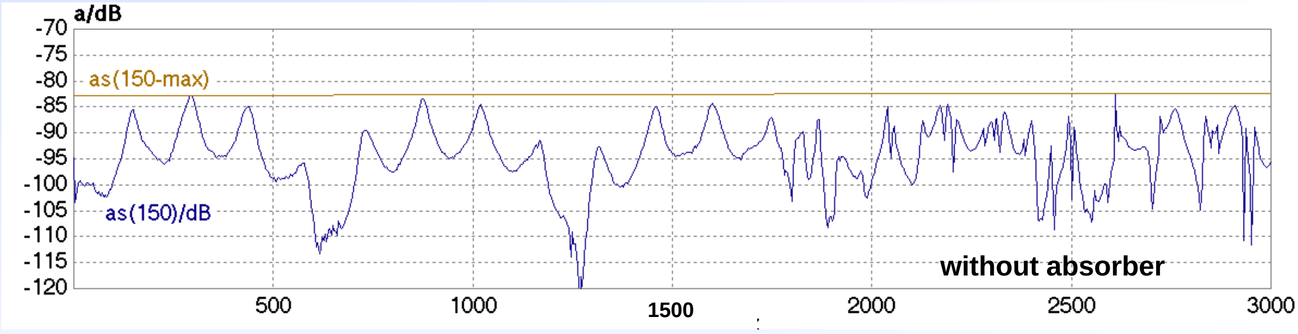
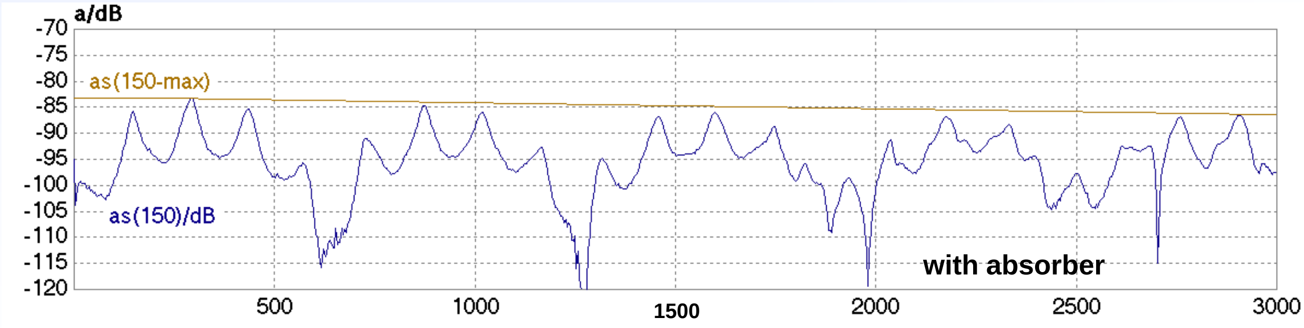
RG 214 in “Absorber – Cell“ 1000/150/150





increase of a_S of about 3 dB at 3 GHz

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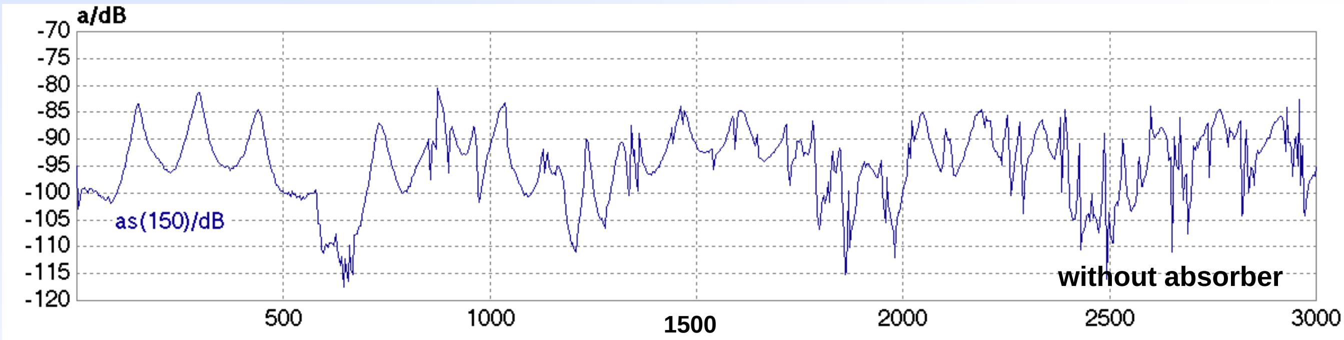
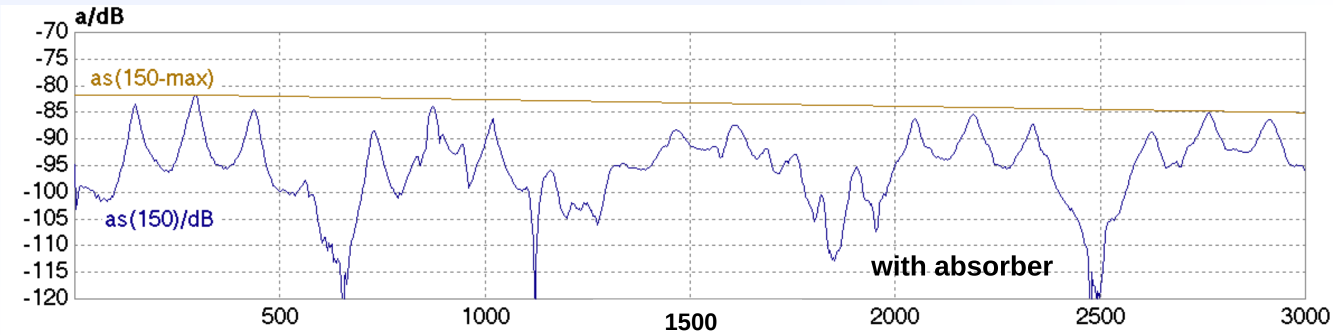
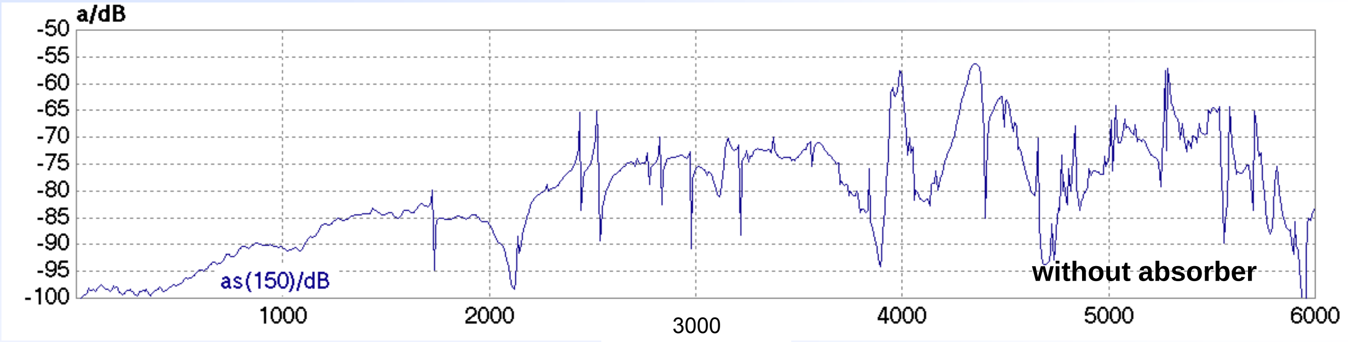
RG 214 in “Absorber – Cell“ 1000/300/300

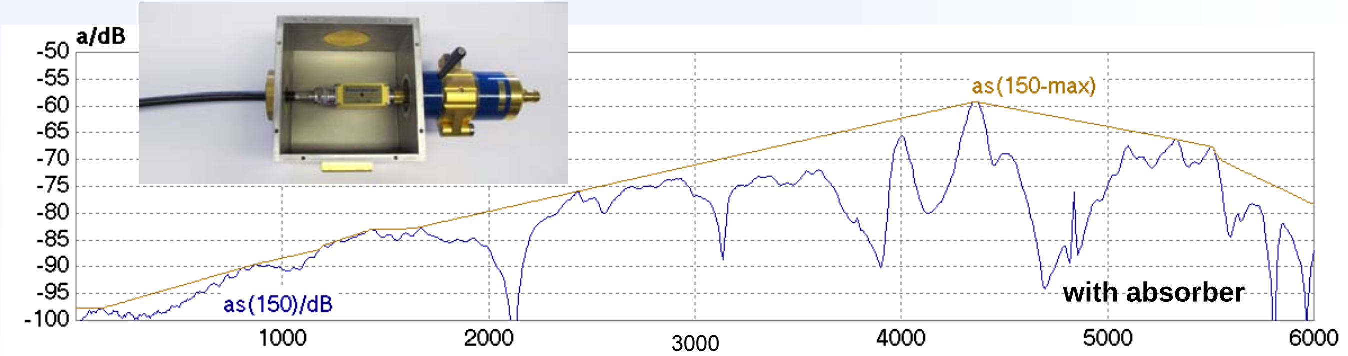




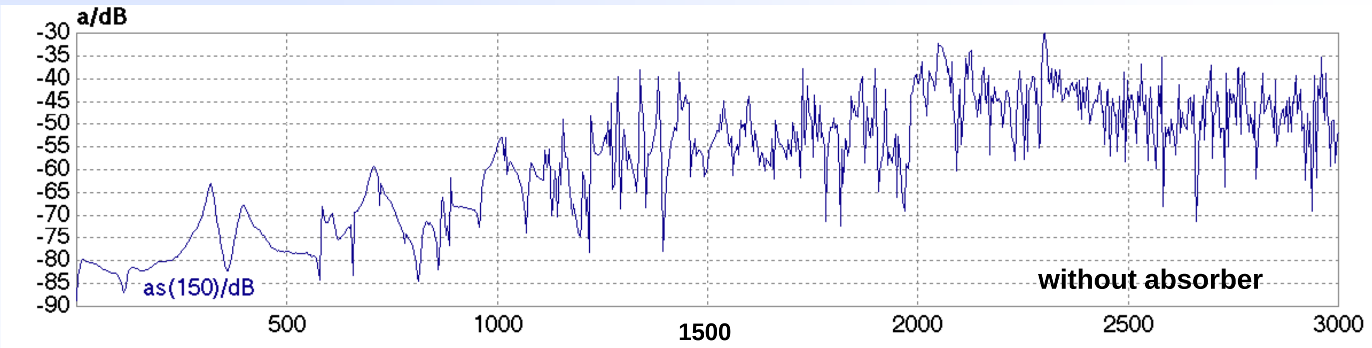
increase of a_S of about 3dB at 3 GHz

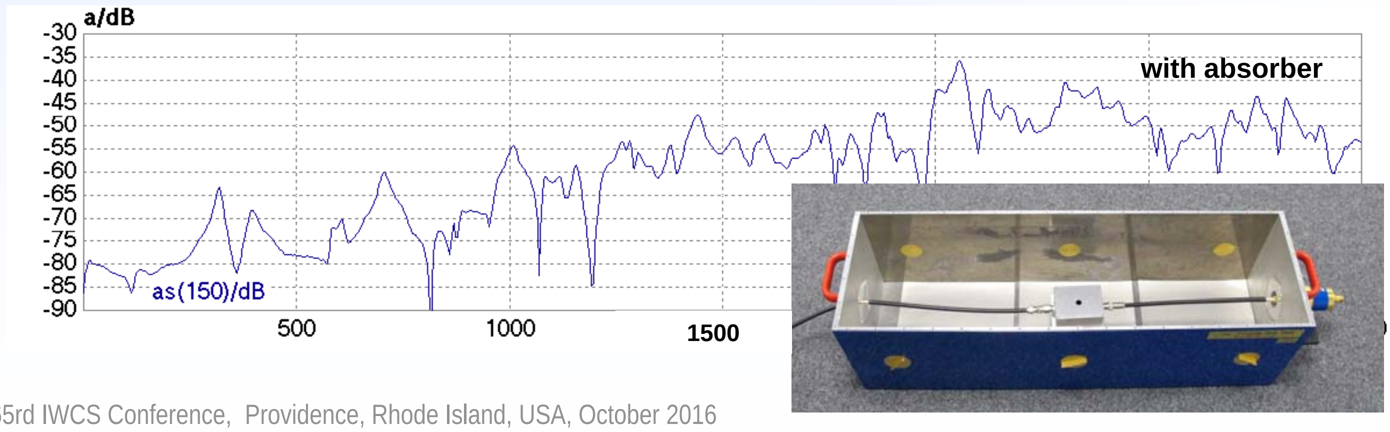
Box with hole in “Absorber – Cell“ 140/140/100





Box with hole in “Absorber – Cell“ 1000/300/300





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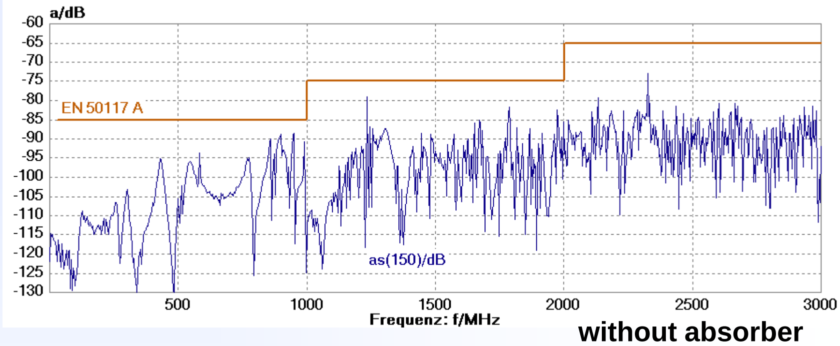
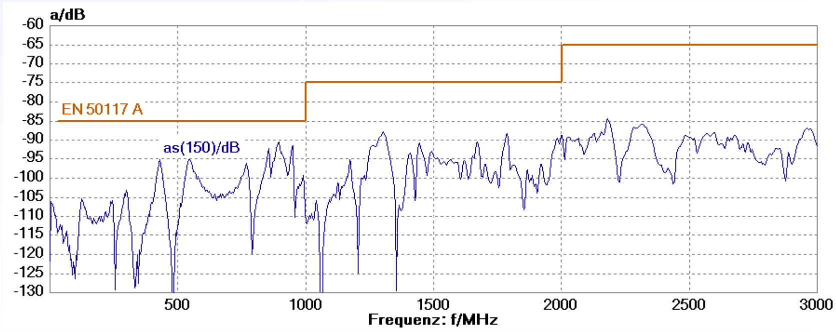
CATV-Tap-off with Triaxial Cell 1000/300/300



without absorber



with absorber 3x30x30, 5mm

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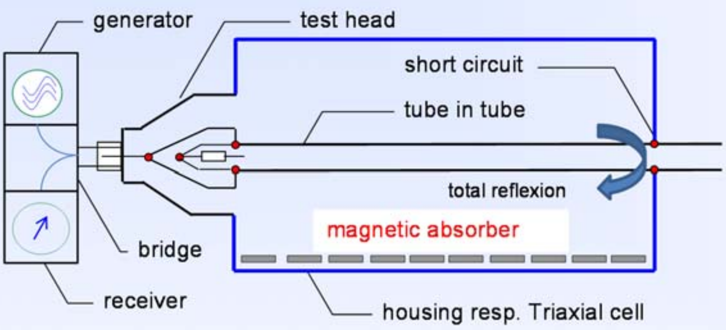
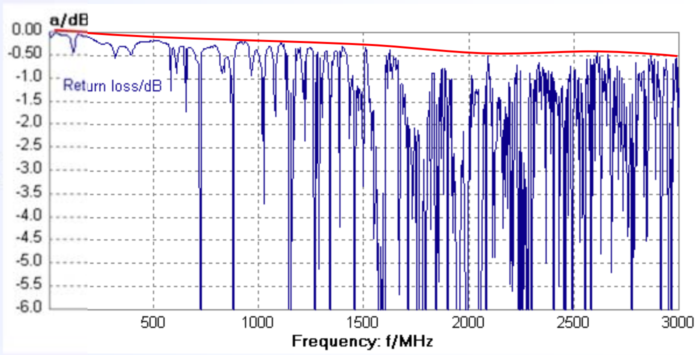
Return loss, 1000/300/300



Principle of return loss measurement

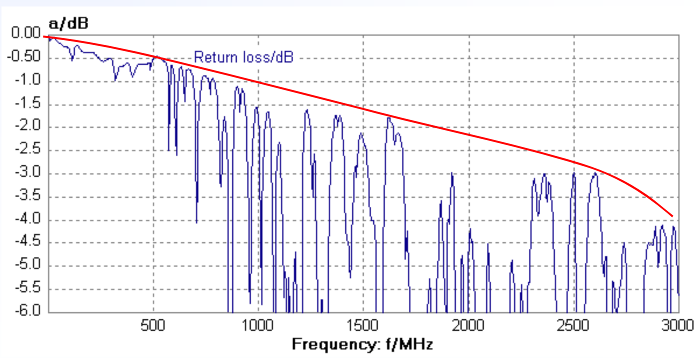


without absorber

Max. values of Return loss shows in principle the attenuation of the outer system

The additional attenuation of the Cell with absorber is about 3,5 dB at 3 GHz with tube 1000/300/300, which is in principle the same value as found as difference of the measurements of RG 214 in the tube CoMeT 40 and with the Cell 1000/300/300,(sheet 16).

It could be used for measurement correction (ffs).



with absorber

Conclusion

- The Triaxial test procedure is a well established procedure to measure Transfer impedance Z_T and Screening attenuation a_S on communication cables, connectors and components
- To measure larger components, the Triaxial Cell was developed
- The drawback of the Triaxial Cell are higher order modes which limits measurements in the range of TEM wave propagation.
- The problem can be solved easily by using absorber material like ferrites or magnetic absorbers in the Triaxial "Absorber Cell"
- Higer order modes can be supressed and the usable frequency range can be extended up to and above 3 GHz.
- Therewith, a simple and easy test method of screening effectiveness of connectors and components is given from DC up to and above 3 GHz
- IEC 62153-4-15 will be revised accordingly.
- Further questions: *bmund@bedea.com*

Thank you
for your attention

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Progress of International Standards for Triaxial Procedure

TS 62153-4-1	Introduction to electromagnetic (EMC) screening measurements	2014-01	**published**
62153-4-3Ed2	Surface transfer impedance - Triaxial method	2013-10	**published**
62153-4-4Ed2	Shielded screening attenuation, test method for measuring of the screening attenuation a_S up to and above 3 GHz	2015-04	**published**
62153-4-7Ed2	Shielded screening attenuation test method for measuring the Transfer impedance Z_T and the screening attenuation a_S or the coupling attenuation a_C of RF-Connectors and assemblies up to and above 3 GHz, Tube in tube method	2015-12	**published**
62153-4-9	Electromagnetic Compatibility (EMC) – Coupling attenuation, triaxial method	2008-03	Revision in preparation
62153-4-10Ed2	Shielded screening attenuation test method for measuring the Screening Effectiveness of Feedtroughs and Electromagnetic Gaskets	2015-11	**published**
62153-4-15	Test method for measuring transfer impedance and screening attenuation - or coupling attenuation with Triaxial Cell	2015-12	Revision in preparation
62153-4-16	Relationship between surface transfer impedance and screening attenuation, Conversion a_S and Z_T	2016-08	46/615/FDIS

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Literature

[1] R. Lorch and G. Mönich, “Mode suppression in TEM cells”, Proc. IEEE symposium, Santa Clara, CA, USA, Aug. 1996, pp. 40-42.

[2] B. Mund and T. Schmid, “Measuring EMC of HV cables & components with the Triaxial Cell”, Wire & Cable Technology International, January/March 2012.

[3] Lauri Halme and Bernhard Mund, “EMC of cables connectors and components with Triaxial test set-up”, Proceedings of the 62nd IWCS Conference, Charlotte, USA, pp 83 – 90, Nov. 2013.

[4] D. Pouhè and G. Mönich, “On the interplay between equipment under test and TEM cells,” IEEE Trans. Electromagn. Compat, vol. 50, no. 1, pp. 3-12, Feb. 2008.

[5] D. Pouhè, “Mutual influence between the equipment under test and TEM cells”, IEEE Trans. Electromagm. Compat., vol. 54, No. 4, pp. 726-737, Aug. 2012.

[6] IEC 61000-4-20 Electromagnetic compatibility (EMC) – Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides, 2011

[7] Ismar Lucicanin, Optimierung der Triaxialen Zelle, Praktikumsbericht, HS-Reutlingen & bedea Asslar, October 2016